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POSITIVE RAYS

by

Sister Mary Samuela Murray, O. S. D.

A Thesis Submitted for the Degree of

Bachelor of Arts

University of Wisconsin

1918

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CONTENTS

	Page
General Description.	1
Apparatus used.	2
Colours Produced by Positive Rays.	3
Direction of Propagation of Positive Rays.	5
Deflection of Positive Rays by Electric and Magnetic Forces. . . .	6
Theory of the Deflection of a Moving Electrified Particle. .	6
Wien's Experiment.	9
Thomson's Experiment.	11
Application of Positive Rays to Molecular Analysis.	15
Study of Some Typical Positive Ray Photographs.	18
Advantages of the New Method of Analysis.	21
Limitations of the New Method.	21
Acknowledgment.	
Bibliography.	

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Positive Rays

General Description

The general appearance of an ordinary discharge tube is quite familiar. Fig. I gives a diagrammatic representation. The cathode C is covered with the velvety light, commonly known as the cathode glow. Beyond this is a rather dark space named in honor of its discoverer, the Crookes dark space. The width of this

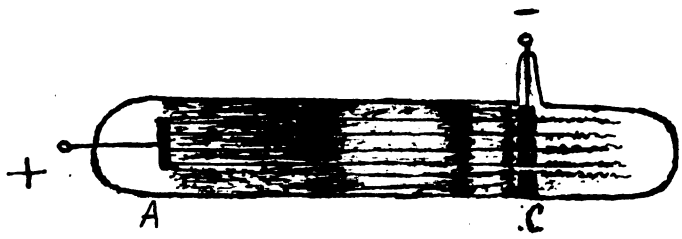

Fig. I. Discharge Tube

space varies inversely with the pressure in the tube, so that if the pressure is high this dark space may be practically invisible. Beyond the Crookes dark space is a luminous area, the negative glow, bounded on the side remote from the cathode by another dark area, the Faraday dark space. The length of the tube occupied by these phenomena is in the main, dependent on the gas pressure and practically independent of the size of the tube. The remainder of the tube is filled with a bright light known as the positive column, which often is divided into numerous striae.

If the pressure is fairly low one may distinguish an additional phenomenon. This consists of faint bluish streams of light the cathode rays which proceed normally from the cathode and penetrate in straight lines across one or more of the dark spaces. As the pressure reduction continues these rays become more important, penetrating further and further until they at last fall upon the walls of the tube, exciting there the characteristic greenish phosphorescence. Keeping pace with the extension of these rays,

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the Crookes dark has grown until it practically fills the whole tube, the rest of the ordinary discharge being represented by a glow on the cathode and a single light patch on the anode itself.

It had long been known that if a solid obstruction were placed in the patch of the discharge, the cathode rays would cast the shadow of the object on the opposite wall of the tube. It was then noticed that if the obstacle were placed in the Crookes dark space that a shadow was also cast on the cathode. This was equivalent to saying that there must be rays in the tube proceeding in a direction opposite to the cathode and falling upon it.

Apparatus

It was these very rays that Goldstein discovered in 1886. The apparatus he used is represented in Fig. 2. The cathode C was a metal plate which stretched across the tube. Into this plate a

Fig. 2

number of holes were drilled, the diameter being less than the thickness of the plate. The anode a was at the lower end of the tube. The gas pressure was kept so low that when the electrode were connected with the induction coil and a discharge passed through the tube the dark space below the cathode was very conspicuous. Goldstein found that under these conditions that slightly diverging bundles of a luminous discharge referred to

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above passed through the holes of the cathode and streamed into the upper tube. Because these rays streamed through holes or channels Goldstein called them "Kanalstrahlen". But now since they have been proved to be streams of the particles, the greater number of which are positive, they are called positive rays.

Colours Produced by Rays

The colour of the light in these bundles depends on the kind of gas that filled the tube: when air was used the light was yellowish, when hydrogen was used, the colour was rose.

Goldstein used also in his earlier experiments a tube such as is represented in Fig. 3. The cathode which entirely fills the tube is a flat disc with a hole in it; a metal tube fitting into

Fig. 3

the hole is soldered on to the cathode. The length of the tube is several times the diameter of the hole. The anode a is fused into the upper part of the tube. With a properly adjusted pressure the positive rays stream through the cathode tube into the lower part of the vessel and the cathode rays shoot upward.

Sir J. J. Thomson says that he found neon gas to give the

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striking results. The light due to the positive rays is a brilliant red, while that due to the cathode is a pale blue. If helium is used the positive rays give a reddish light, the cathode, green.

When the positive rays strike against the walls of the tube they produce a phosphorescence of the glass. This phenomenon is characteristic of the cathode, but the phosphorescence of the positive rays is much dimmer. With German glass the positive and cathode rays produce a lighter and darker green, respectively. With lithium chloride the phosphorescence produced by the positive rays is a bright red which yields the red lithium line when examined with the spectroscope: the phosphorescence due to the cathode is a light blue, giving a continuous spectrum.

Goldstein relates in Phil. Mag. VI, p 372, 1908, that positive rays come readily from the space between two parallel plates connected metallically together and used as a cathode for the discharge through a low pressure gas. Cathode rays also arise here but if a gas is used that shows marked difference in the color of the luminosity between the positive and cathode rays very interesting features are presented. For this purpose hydrogen, helium, or neon are particularly suitable. If a cathode formed of two parallel equilateral triangles connected by a wire is used for a discharge in helium at low pressure the discharge near the cathode has the appearance of Fig. 4. From the points of the triangle stream luminous rays of the characteristic red color of positive rays in helium while from the middle points of the sides are the origin of streams of greenish luminosity, the color of the path of the cathode rays through helium. If at this stage a small magnet is brought near the discharge tube the green rays are readily

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Fig. 4.

deflected while no effect is produced on the red rays. Cathodes of various shapes have been substituted for the two parallel equilateral triangles with very interesting results. Kunz and Orange have made interesting researches on this phase of the work.

Direction of Propagation of the Positive Rays

By placing a solid body in the path of a pencil of positive rays a shadow is cast on the part of the tube that was phosphorescing under the impact of the rays. By comparing the shadow with the object, it is found that the shadow is approximately the projection of the outside of the solid on the walls of the tube by lines passing through the single hole in the cathode if the cathode of Fig. 3 is used or if that of Fig. 2 is used, by lines passing through the holes in the cathode. From Fig. 5 it is readily seen

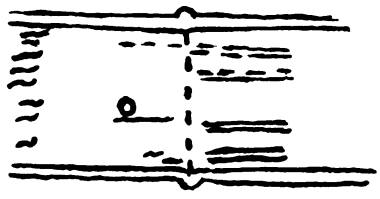

Fig. 5

that the direction of propagation is first determined by Goldstein without magnetic of electrostatic interference is straight lines.

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Deflection of Positive Rays by Electric and Magnetic Forces

Early in their history cathode rays were proved to be negatively electrified by the study of the deflection they experienced when acted on by magnetic and electric forces. Besides, these deflections gave the means of finding the mass and velocity of the cathode particles. On the discovery of positive rays similar attempts were made on them. However, for twelve years after their discovery no effect of a magnetic field was detected. Yet, as previously said, a small hand magnet produced an appreciable effect on the cathode rays. In 1898 by means of a very powerful magnetic field, Wien proved that positive were deflected by magnetic forces.

Theory of the Deflection of a Moving Electrified Particle

a. By a Magnetic Field:

The force acting on the particle is at right angles to the magnetic force, at right angles likewise to the direction of motion of the particle and equal to $e\,H\,v \sin \phi$, where e is the charge, on the particle, V is its velocity, ϕ is the angle between H, the field strength, and V. Since force is always at right angles to the direction of motion of the particle there will be no alteration in speed but only in the direction of the motion of the particle. If particle is originally projected with a velocity V parallel to the X-axis, and the field is in the direction of the Z axis the direction of the force will be parallel to the y axis and this will be the direction in which it will be deflected. If y is the deflection in this direction at the time t, m the mass the particle, H the magnetic force parallel to the axis Z and e the charge on the particle the equation of motion is

$$m \frac{d^2 y}{d t^2} = e H \frac{dx}{dt}$$

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Integrating this equation we get

$$m\frac{dy}{dt} = \int_0^t e\,H\,\frac{dx}{dt}\,dt = \int_0^x e\,H\,dx \qquad (1)$$

$\frac{dy}{dx} = 0$ when $x = 0$. If the deflection of the particle is small

$$\frac{dx}{dt} = v$$

and $\frac{dy}{dt} = v\frac{dy}{dx}$ Then (1) may be written $mv\frac{dy}{dx} = \int_0^x e\,H.\,dx$

hence if y is the deflection when x = l

$$m\,v\,Y = \int_0^l \left\{ \int_0^x e\,H\,dx \right\} dx$$

integrating by parts we have

$$m\,v\,Y = l\int_0^l e\,H\,dx - \int_0^l xe\,H\,dx$$

$$= e\int_0^l (l-x)\,H\,dx$$

Write A for

$$\int_0^l (l-x)\,H\,dx$$

$$y = \frac{e}{mv}A$$

A depends upon the strength of the magnetic field and the distance from the point of projection at which the deflection is measured.

b. By an Electrostatic Field:

If the particle is projected with a velocity V parallel to the axis of X, the electric force acting of particle be parallel to the axis z and equal to Z, then the equation of motion of the particle under the electric force is

$$m\frac{d^2z}{dt^2} = eZ$$

When deflection is small, $\frac{d^2z}{dt^2} = v^2\frac{d^2z}{dx^2}$ approx.,

hence $$mv^2\frac{d^2z}{dt^2} = eZ$$

or $$Z = \frac{e}{mv^2}\int_0^l \left(\int_0^l Z\,dx\right)dx$$

$$= \frac{e}{mv^2}B$$

where $B = \int_0^l \left(\int_0^l Z\,dx\right)dx$

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B depends merely on the distribution of the electric field and the distance from the point of projection at which the deflection is measured.

c. By a Combination of Both Magnetic and Electric Forces:

If the particle is simultaneously acted on by magnetic and electric forces parallel to the Z axis and hence parallel to each other, we may if the deflections are small superimpose the effects due to the two different forces so that the y and z deflections of the particle parallel to the y and z axis respectively are given by the equation

$$y = \frac{e}{mv} A \quad (1)$$

$$z = \frac{e}{mv^2} B \quad (2)$$

If we had a stream of charged particles of different kinds (different values for $\frac{e}{m}$) projected from the origin with different velocities parallel to the x-axis, in the absence of electric and magnetic forces they would strike the screen at the same point. But when the particles are submitted to the action of electric and magnetic fields the particles get sorted and no two strike the screen at the same place unless they have the same speed and the same $\frac{e}{m}$. If we know the deflected position of the particle by equations (1) and (2) we can calculate both the values of v and $\frac{e}{m}$; we have

$$v = \frac{y}{z} \frac{B}{A} \quad (3)$$

$$\frac{e}{m} = \frac{y^2}{z} \frac{B}{A^2} \quad (4)$$

$\frac{y}{z}$ will be constant for all particles moving with a given speed regardless of charge or mass and such particles will strike the screen in a straight line passing through the undeflected position of the particles.

$\frac{y^2}{z}$ will be constant for the same kind of particles, regardless of their speed, hence particles of the same kind will strike the

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screen in a parabola with its vertex at the undeflected position of the particles, and there will be as many of these parabolas as there are different kinds of particles.

Wien's Experiment

By applying the above method Wien demonstrated the electric and magnetic deflections of the positive rays. In this wise he proved that positive rays contain electrified particles and that the direction of their deflection, which was just opposite to that of the cathode rays proved the particles were positively charged. He was able to calculate both the v and $\frac{e}{m}$ for these particles.

The appartus he used is shown in Fig. 6. The cathode K is an iron cylinder 5 cm. long with a holed 2 mm. bored through it. At the top of the tube the anode was plased. The opposite end of the tube was flat to permit accurate observations of the luminosity produced by positive ray impacts on the glass. The magnetic field is produced by the electromagnet whose poles are N

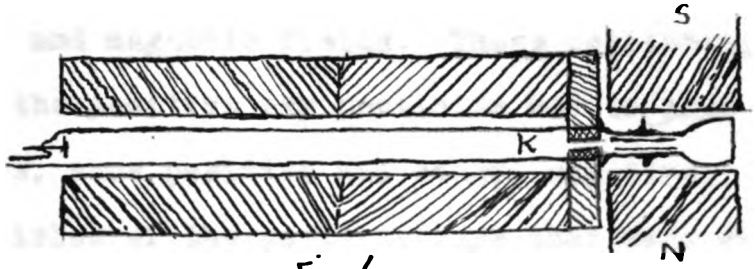

Fig. 6

and S. The part of the tube through which the discharge is passing was shielded from the magnetic field by surrounding it with thick sheets of soft iron. The electrostatic field was produced between two parallel metal plates connected with the terminals of a voltaic battery. When both fields were acting the round phosphorescent spot due to the impact of the positive rays was drawn out into a straight band. Since the band was straight the velocities of all the different particles producing it are the same

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but the $\frac{e}{m}$ values would all be different. Wien found if the tube was filled with H that the value of the $\frac{e}{m}$ for the most deflected portion was 7545, the value of the e/m for charged atom of hydrogen in the electrolysis of water is 10,000.

The deflections of these rays by electric and magnetic fields show they are positively charged particles and the $\frac{e}{m}$ values show them of much greater mass than the cathode rays whose $\frac{e}{m} = 1.7 \times 10^{7}$. The displaced particles being in a straight band indicated that the $\frac{e}{m}$ varied from zero up to 10,000. Now if the charges were all the same then the masses must vary from the mass of hydrogen atom up to a comparatively larger mass. This continuous variation in the $\frac{e}{m}$ value is contrary to the molecular theory.

In 1906 J. J. Thomson showed that the differences between the theory and the experiments were due to the high pressure of the gas. Due to this, the particles forming the positive rays collided with the gas molecules while they were passing through the electric and magnetic fields. These collisions ionized the gas so that the positive ray particles had to pass gas full of charged particles, some positive and others negative. As a result some of the particles of the positive rays that were charged were neutralized before they passed through the fields and hence they did not receive full deflections. Other positive ray particles that were neutralized before entering the field struck against a corpuscle or an atom and were ionized by collision and lost a negative corpuscle. These latter were then positive and were deflected by an amount depending upon the place in their path where they picked up the charge. This condition of affairs make A and B used in equations (3) and (4) vary from particle to particle and the $\frac{e}{m}$ can not be obtained from the above equations.

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Thomson's Experiment

Thomson obviated these difficulties by an arrangement similar to Fig. 7.

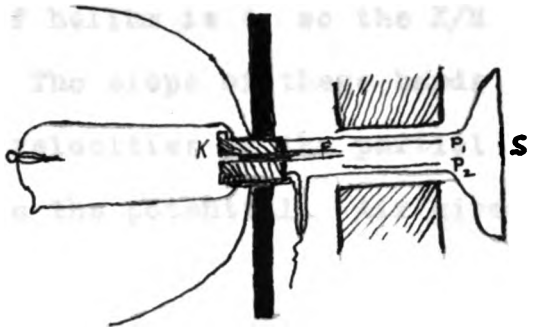

Fig. 7.

The cathode K had a hole bored through it and into this hole a fine bored tube P was firmly fixed. The screen S was willemite which phosphoresces brightly. The usual magnetic and electrostatic fields were present as likewise a magnetic shield of soft iron.

When the gas pressure was low, according to J. J. Thomson, the phosphorescence was drawn out into two straight bands as in Fig. 8. The value of $\frac{e}{m}$ for the most deflected part of the band

Fig. 8

Fig. 9

was 10^4, for the other band 5×10^3. These values are the $\frac{e}{m}$ values for the hydrogen atom and molecule, respectively, and suggests that one band is due to hydrogen atoms, the other to hydrogen molecules. Fig. 9 shows the result of using helium. Three bands are present. The values of the $\frac{e}{m}$ are respectively 10^4, 5×10^3, 2.5×10^3 which

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indicates the presence of hydrogen atoms in the first, hydrogen molecules in the second, and helium atoms in the third band. The atomic weight of helium is 4, so the H/H is one-fourth that of the hydrogen atom. The slope of these bands show practically no variations in the velocities of the particles which is little affected by charges in the potential. Air gives the same two lines as in Fig. 8.

In both Fig. 8 and Fig. 9 there is a faint band deflected in the opposite direction which must therefore be due to particles with negative charge. The $\frac{e}{m}$ value is 10^4 so these negative particles are not cathode rays.

When the pressure was reduced to the lowest possible value J. J. Thomson observed a remarkably different form of luminosity on the screen. At these low pressures there is great need of precautions with the tube for it is hard to get the discharge to pass through the moderate size tubes. The result is that there is danger of sparks breaking the tube. This is obviated by facing the cathode with a thin layer of calcium or by smearing the face of the cathode with a liquid alloy of sodium and potassium. At these low pressures the straight bands of Figs. 8 and 9 are replaced by two parabolas of Fig. 10. The same values of 10^4

Fig. 10

and 5×10^3 for the $\frac{e}{m}$ held. The negative luminosity has vanished but the undeflected spot is still luminous.

J. J. Thomson found that it was a great advantage to use

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large glass vessels for low pressure. As a result of this Fig. 11 shows the greater portion of the Positive Ray apparatus which is at present used at the Cavendish Laboratory. The apparatus consists of two parts, the discharge tube proper where the particles

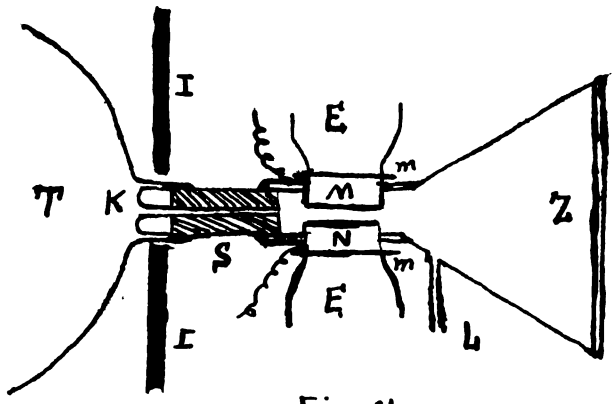

Fig. 11.

are produced and the camera where they are detected, and their masses determined. The discharge tube is really a large bulb or flask T with a volume of from one to two litres. The anode is placed in a side tube not shown in the Fig. The cathode K is placed in the neck of the flask. The shape of the cathode is shown in detail in Fig. 12; the face is aluminum, the rest is soft iron. A tube is bored through the cathode to admit a very fine bore copper tube of a length of 7 cm. Besides this iron shield for the copper tube, II is a magnetic shield for the main discharge.

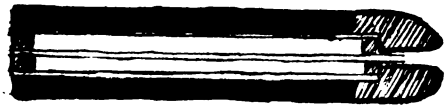

Fig. 12.

The gas to be experimented on is admitted into the flask T by a side tube and is removed by a Gaede pump (not shown in diagram) which always keeps the gas at a suitably low pressure. The

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cathode is kept cool by means of a water cooling jacket.

When the rays pass through the copper tube they pass between M and N two soft iron blocks let in through the sides of the tube (here made of ebonite) and carefully sealed so as to be vacuum tight. These blocks serve a two-fold purpose. First, they form the pole pieces of the electromagnet E E from which they are electrically insulated by mica sheets m, m. By this means they can be charged positively and negatively, respectively by means of small storage batteries and hence serve as the electrodes for the application of the electrostatic field.

This arrangement permits of a subjection of the positive particles simultaneously to both an electrostatic and magnetic field which are placed parallel to each other thereby causing deflections at right angles to each other.

After passing through these fields the rays fall either upon the glass plate Z covered with powdered willemite or a photographic plate, which by a suitable device can be introduced in front of Z.

The side tube L leads to a tube filled with charcoal and immersed in liquid air. This latter is Dewar's device for absorbing as far as possible the gases in this part of the apparatus. It has been found that if the gas in the camera is at the same pressure as the gas in the discharge tube the effects on the screen are entirely secondary. The gas in the camera becomes ionized by the action of the rays. Then the rays are left to travel through an atmosphere charged with negative electrons with which they readily combine to form neutral molecules again. When this has taken place the electrostatic and magnetic fields can no longer act on it, so the extent of the deflection will

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depend upon the length of time during which it succeeds in retaining its charge. The charcoal and liquid air make it possible to keep the pressure in the camera really lower than that in the discharge tube thus rendering diffusion along the copper tube extremely slow.

Application of Positive Rays to Molecular Analysis

To appreciate this new method of analysis it will be well to follow with J. A. Crowther of the Cavendish Laboratory the course of a positive particle from its generation in the discharge tube to its stoppage on the photographic plate. If the particle is formed near the anode it will first of all experience a fall of about 30,000 or 40,000 volts, the potential difference of the two electrodes. The energy acquired will be equal to VE, when V is the potential drop and E is the charge on the particle. The velocity v, on reaching the cathode will be

$$v^2 = 2V\,E/M$$

This is maximum velocity. Any particle forming nearer the cathode will of course experience a less potential drop and consequently will have a lesser velocity. So the stream of particles passing through the cathode will contain particles with all velocities up to the maximum.

On passing through the electric and magnetic fields the particles will be acted on by force XE and HEv, where X is the electric and H the magnetic field. These forces will cause the point at which the particles strike the screen Z in Fig. 10 to be deflected through the distances shown in equations (1) and (2). These deflections, owing to the two fields being parallel, are at right angles to each other.

To get a clearer conception of the positive ray parabolas it will be well to refer to a Fig. 13, which is a diagram, closely

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related to one given by J. A. Crowther in his Molecular Physics.

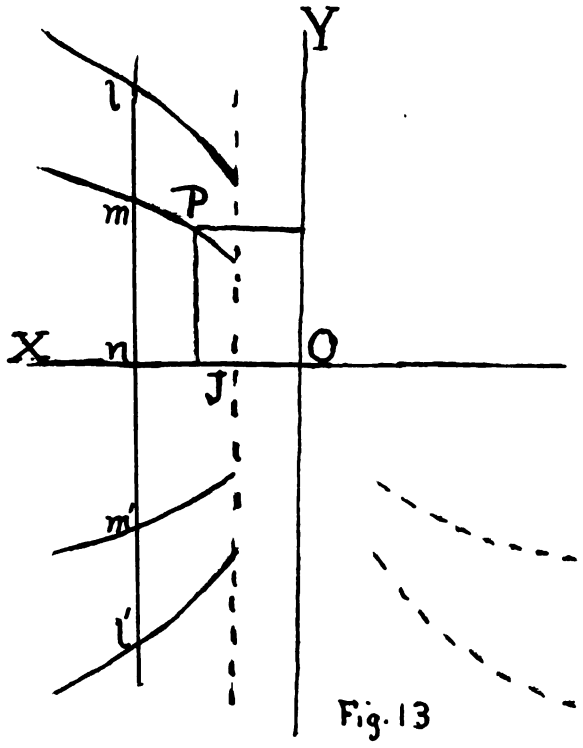

Fig. 13

If O represents the position on the plate or screen of the undeflected ray, then OX and OY are the directions of the electric and magnetic deflections, and P will represent the point O after deflection. The ratio y/x is the measure of the velocity and y^2/x is the ratio of the mass to the charge, or m/e.

If all the particles were identical and had the same velocity the spot O would simply be shifted to the point P. But the velocities of the particles differ so the rays will be drawn out into a line even if their mass and charge are identical. By equation (4) all particles whose M/E is the same will line on some curve whose value y^2/x is constant; such a curve is a parabola.

If the particles emerging from the cathode consist of atoms of different atomic weight, they will be sorted out into a series of parabolas one above the other, each curve having its own definite value of m/e. Since the velocity proportional to y/x can not exceed a certain value these curves will stop short at a definite distance from the O Y axis. So the photographic plate will

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look like the upper left-hand quadrant of Fig. 13 with two parabolas. By reversing the field half way through the exposure symmetrical parabolas are formed on the opposite side of O X.

To measure the curves draw any perpendicular on the O X cutting the curves at l, m, and the axis at n. Then

$$\overline{ln}^2/\overline{mn}^2 = y_2^2/y_1^2 = \left(\frac{m_2}{E_2}\right) \div \frac{m_1}{E_1}$$

If $E_1 = E_2$, or the two particles carry the same charges, the ratio of the masses is simply the ratio of the lines

Of course the line O X is not on the plate but the apparatus is so arranged that the direction of the deflections are parallel to the edge of the plate, while O is always marked by a very bright spot caused by the rays that come through the cathode uncharged and hence are not deflected.

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Study of Some Typical Positive Ray Photographs.

The ratio of the squares of these ordinates of the parabolas do not directly give the ratio of the masses of the particles but rather the ratio of their electro chemical equivalents. By far the greater majority of the particles carry the single electronic charge e, while in any case the charge E can be only a small integral multiple of this. Little uncertainty arises from this yet some does occur. In this regard mercury is particularly striking for mercury atoms carrying as many as eight charges have been detected. In Plate I, five of the six parabolas which is really a copy of one of Prof. Thomson's photographs, are due to atoms of mercury with one, two, three, four, and eight charges. Some of the lines are too faint to show up in the copy.

Plate II gives a copy of a typical positive ray photograph. The gas used here was atmospheric nitrogen obtained by extracting the oxygen from the air. Table I contains the actual measurements made on the plate.

The first column gives the distance of the different parabolas from the O X axis measured along a common ordinate. The second column the M/E values deduced from these figures, assuming that they all carry the same charge. If the charge is double or treble the corresponding mass will be half, one-third, etc. The standard line on Plate II is the innermost, which as its position shows is due to mercury carrying a single charge. The mass is taken for convenience as equal to its atomic weight.

From the table it is evident that the three inner parabolas represent particles with M/E values of 200, ½. (200), 1/3.(200). They are due to mercury atoms having one, two, and three charges, respectively. Mercury vapor is always present in the tube unless

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Plate I

Parabola due
multiple-charged
Mercury atoms.

(from "Molecular Physics").

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Plate II

Typical Positive Ray
Photograph.
(from "Molecular Physics")

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Nitrogen. Potential across discharge tube, 3000 volts; current through magnet, 3.5 amperes; potential difference in electric field, 200 volts

d m. m.	M/E		Probable cause of the line
7.2	200	Hg^+	Mercury atom with single charge
10.3	100	Hg^{++}	Mercury atom with two charges
12.4	67	Hg^{+++}	Mercury atom with three charges
15.4	44	CO_2^+	Molecule of carbon dioxide
16.5	39	A^+	Argon atom with single charge
19.4	28	N_2^+	Nitrogen molecule with single charge
23.1	20	Ne^+	Neon with a single charge
25.6	15.9	O^+	Atom of oxigen with a single charge
27.6	14	N^+	Nitrogen atom with single charge
30	12	C^+	Carbon atom with single charge
38.7	7	N^{++}	Nitrogen atom with two charges

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precautions are used for its exclusion, for it is used in the vacuum pump. The next line is made by particles having a mass 44, these singly charged molecules of carbon dioxide; carbon impurities are usually present. The argon line is the long bright line below the very thick bright line due to molecules of nitrogen with a single positive charge. This is of course the most prominent line on the photograph. The remaining lines in order are the Ne, O, N, C and H atoms, the last H having two charges. The hydrogen line is deflected off the plate entirely.

It can be readily seen that no line on the plate is unexplained and the value obtained of the relative masses correspond very closely to the atomic and molecular weights determined by chemistry.

Some faint lines quite prominent in the plate from which this Plate II is copied are due to the secondary effects which can be obviated only by keeping the exhaustion in the camera chamber much higher than that of the discharge tube. But the mercury parabolas extend almost to the origin for a very different reason. Electric deflection is proportional to charge E, carried by the particle in the electric field divided by $\frac{1}{2} mv^2$. The maximum value of the kinetic energy is equal to V. E , where V is the potential of the discharge and E is the charge carried by the particle in the discharge tube. The minimum electric deflection, that is, the nearest point to which the parabolas can extend will be proportional to E_1/E_2 . This will be the same for all particles, whatever the mass and charge if the particle carries the same charge in the tube as in the camera. Thus all curves will stop short of a certain line parallel to the OY axis.

If the particles in the discharge tube having double or treble charges lose one or more of these extra charges before the electric field is reached the values of E_1/E_2 will be greater than unity

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and the parabolas will extend further toward the OY axis.

Advantages of the New Method of Molecular Analysis

First, it permits the detection with certainty of the presence in a gaseous mixture of far smaller quantities of an element than can be accomplished by any other known method. Professor Thomson proved its delicacy by experimenting on atmospheric argon. With a 2 litre tube and a pressure of 1/300 mm. of mercury he found a faint helium line. At atmospheric pressure the volume of the gas used would be about 1/100 cc. This is approximately the quantity of argon in 1 cc. of air at atmospheric temperature. Thus he was able to detect the helium present in a cubic centimetre of air.

Secondly, it has this advantage in addition over the spectroscope, that it gives directly the atomic and molecular weight of the substance.

Lastly, the time it takes for each single particle to register its presence is extremely minute. A moderate value is 10^8 cm. or 620 miles per second. Their path in the discharge tube is not more than 50 cm. So a particle when caught by the discharge can register itself on the photographic plate in less than one millionth of a second. We can thus expect to find curves corresponding to temporary combinations of atoms so unstable that they exist not longer than one millionth of a second. Thus chemical reactions occurring in the discharge tube can leave traces of not only stable products but intermediate stages.

Limitations of the New Method of Analysis

First, the substance to be experimented on must be either gaseous or capable of exerting a vapor pressure at ordinary temperatures. Again, an element, as in the spectroscope may be present in considerably quantity in the discharge tube without producing a trace on the photographic plate. So far only nickel

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and mercury among metallic elements have been detected by this new method.

It has also been found that the relative intensity of the different lines on a given photograph are far from representing the actual proportion of particles in the stream corresponding to the different lines. A given number of atoms of a light element produce a far greater effect on a plate or screen than the same number of atoms of a heavier element.

J. J. Thomson substituted an electrical for a photographic method of detecting the positive particles. Since all the particles we are dealing with carry an electric charge they can be measured by collecting them in a Faraday cylinder.

To carry out the experiment a brass plate (Fig. 14) was substituted for the glass screen Z in Fig. 11. This plate is covered with willemite. A series of bright parabolas will of course appear on it. If a slit SS is cut in the plate to coincide with one parabola, the particles forming the parabola can be collected in a Faraday cylinder F. placed behind it. The rate of charging up an electrometer connected to the Faraday cylinder will be proportional to the number of particles entering the cylinder per second, that is, to the relative number of molecules which have a mass corresponding to that indicated by the slit. By varying the intensity of the deflecting magnetic field H each one of the parabolas can be brought to coincide with the slit. It can thus be seen that if the other conditions remain the same the value of M/E for a given set of particles is proportional to the square of the strength of the magnetic field. It thus becomes possible to determine the relative proportions of different kinds of atoms and molecules making up a beam of positive rays.

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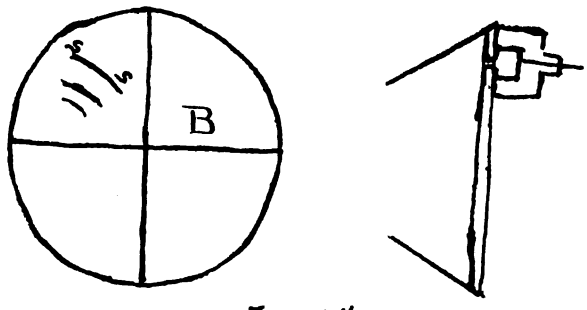

Fig. 14

Yet with all this quantitative analysis of a beam of positive rays further experiment is necessary before it be assumed that the number of atoms of an element in a beam is necessarily proportional to the quantity of the substance present in the discharge tube. Indications seem to point that this is the case for non-metallic elements. If this be true the determination quantitatively of traces of gaseous substances too small to be detected by the spectroscope will then be a reality.

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BIBLIOGRAPHY

Sir J. J. Thomson, 1. Rays of Positive Electricity and their Application to Chemical Analysis.

2. Conduction of Electricity through Gases.

3. Soft Roentgen Rays Produced by Impact of Positive and Slow Cathode Rays.

Phil. Mag. 28, pp. 620-625.

4. Discharge Through Gases.

J. A. Crowther, Molecular Physics (1914)

E. E. Goldstein, Canal-Ray Group

Phil. Mag. Vol 15, 1908, pp. 372

Kanahlen-Strahlen

Annal. Phy. Chem. 64, pp. 38-48 (1898)

E. Wiedeman & G. C. Schmidt: Canal Rays

Annal Phy. Chem. 62,

pp. 468-473, 1897

L. Vegard: Generation of Light by Canal Rays

Ann. d. Phys. 52, pp. 72-100 Feb. 1917.

R. Swinne; Absorption of Solar Positive Rays in the Earth's Atmosphere, Science Abstract Vol. 20

T. Retschinsky: Velocity of Canal Rays

Abstract No. 229, Jan. 1917.

A. J. Dempter: Properties of Slow Canal Rays

Phys. Rev. 8 pp. 651-662, (Dec. 1916)

H. Smith: Comparison of Positive Rays with the Spectrum of the Positive Column in Mixture of He and H.

Phil. Mag. 30, Dec. 1912.

N. Campbell: Ionization by Positive Rays

Chil. Mag. 29, June 15,

Digitized by Google

Digitized by Google

E. Rutherford: Radio-Activity

Oliver Lodge: Electrons.

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Digitized by Google

Approved by W. F. Steve

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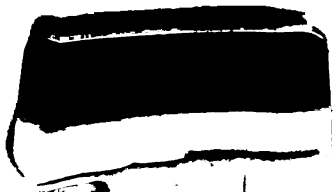

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